SANITATION ON THE ISTHMUS OF PANAMA DURING THE CONSTRUCTIVE PERIOD

BY

S. M. SMITH

ARMOUR INSTITUTE OF TECHNOLOGY

1915

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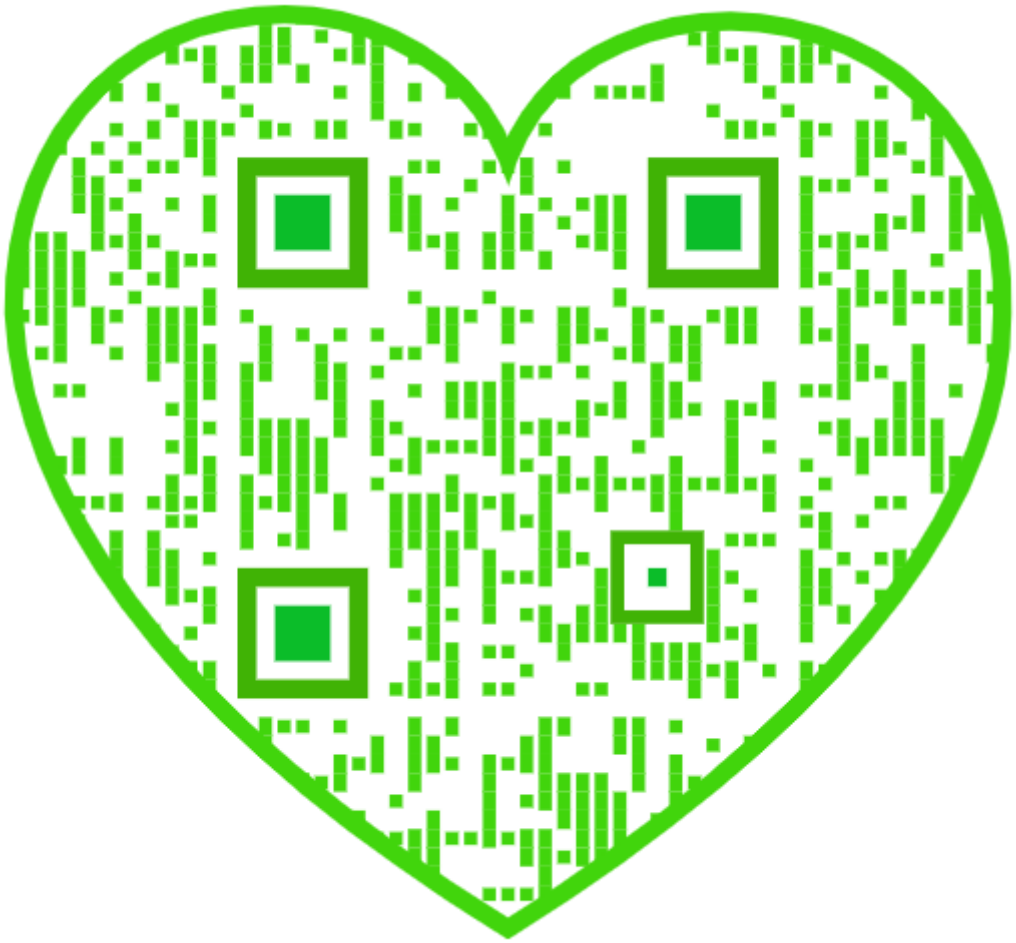

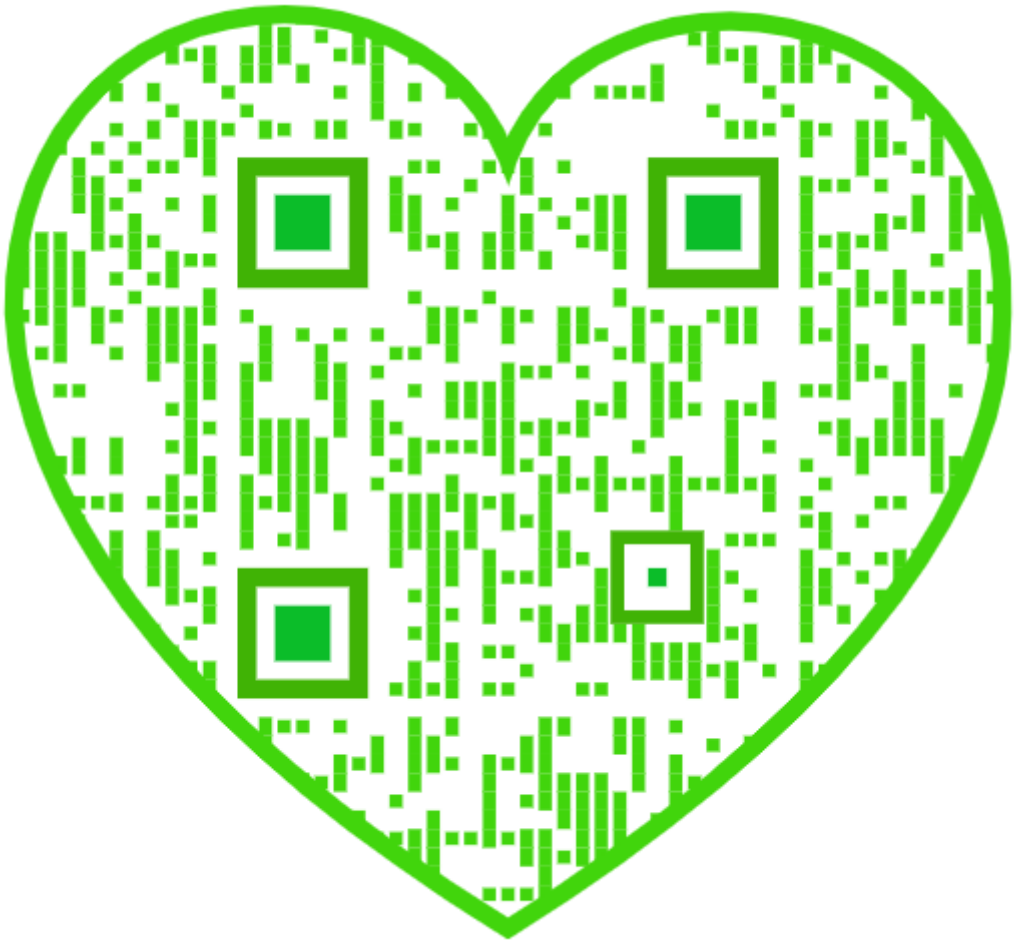

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Sanitation of the Isthmus of
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SANITATION ON THE ISTHMUS OF PANAMA DURING THE CONSTRUCTIVE PERIOD

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Thesis of S. M. Smith to be presented to the Faculty of the Armour Institute of Technology for the Degree of Civil Engineer.

A. B. Phillips
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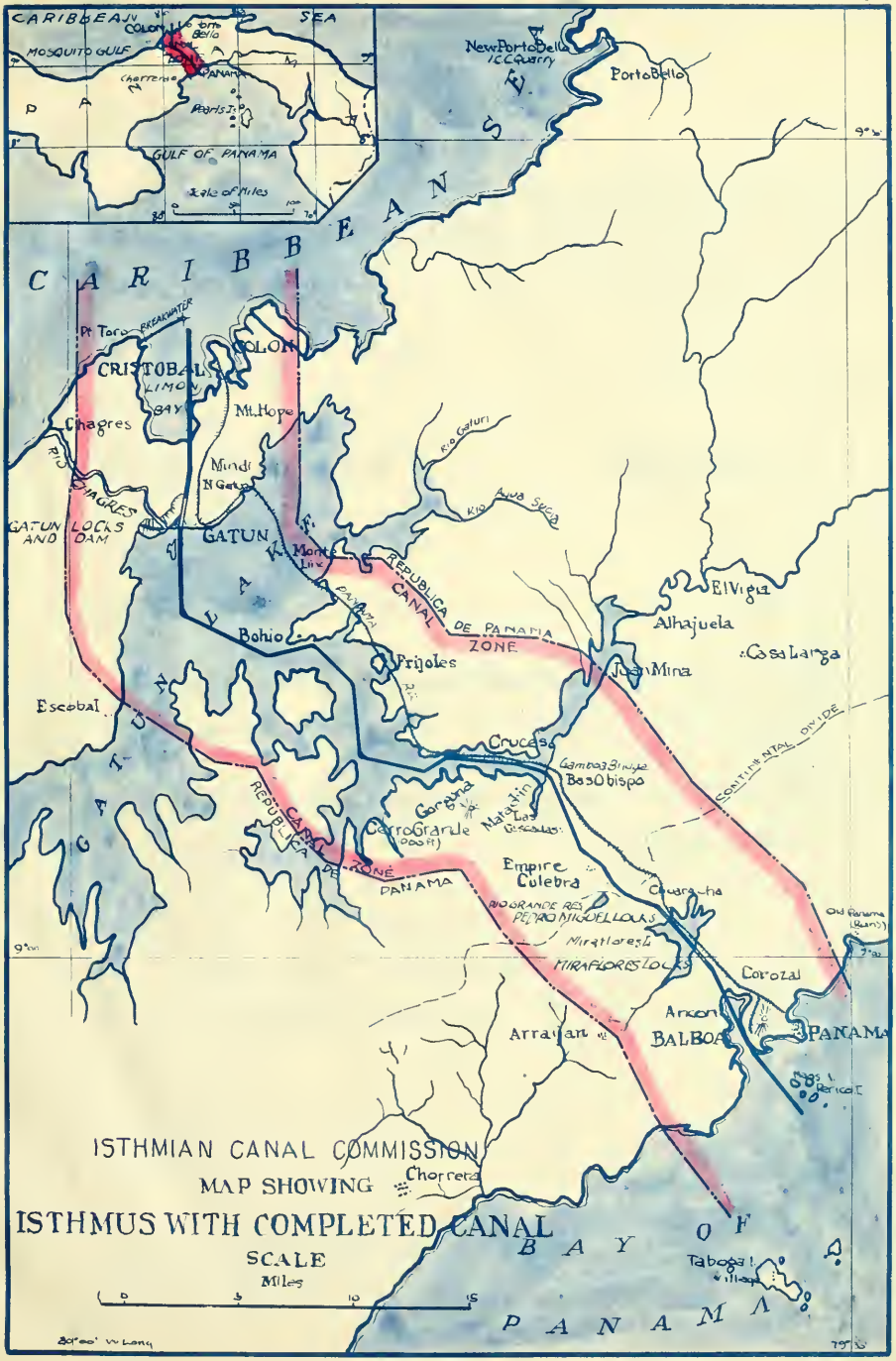
CARIBBEAN SEA
Colon
Ft. Sherman
Ft. de Lesseps
Panama
MOSQUITO GULF
CHAGRES R.
PEARL IS.
GULF OF PANAMA
Scale of Miles
New Portobello
I.C. Quarry
Portobello
CARIBBEAN
Pt Toro
BREAKWATER
COLON
CRISTOBAL
LIMON BAY
Mt. Hope
Chagres
Mindi
N. Gatun
R. Gatun
R. Agua Sucia
CHAGRES R.
GATUN LOCKS AND DAM
GATUN
Monte Lirio
REPUBLICA DE PANAMA
CANAL ZONE
El Viga
Alhajuela
Casa Larga
Bohio
Frijoles
Juan Mina
Escobal
Cucaracha
Gamboa Bifurcation
Bas Obispo
CONTINENTAL DIVIDE
Gorgona
Matachin
Las Cascadas
Cerro Grande (1000 ft)
Empire
Culebra
Cucaracha
RIO GRANDE RES.
PEDRO MIGUEL LOCKS
Miraflores L.
MIRAFLORES LOCKS
Old Panama (Ruins)
Corozal
Arraijan
Arkon
BALBOA
PANAMA
Chorrera
ISTHMIAN CANAL COMMISSION
MAP SHOWING
ISTHMUS WITH COMPLETED CANAL
SCALE
Miles
0 5 10 15
BAY OF
PANAMA
Taboga I.
Village
Boreo W Long

ILLUSTRATIONS

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Map of the Canal Zone - - Frontispiece

Culex and Anopheles - - - - - 9a

Diagram of a Culex Larva - - - - 9b

Special Forms of Drainage Ditches in
the Canal Zone - - - - - 20a

Views of Frijoles from the Sanitary
Office - - - - - - 22a

Office of the District Sanitary
Inspector at Frijoles and
the Sanitary Gang - - - - 30a

SANITATION ON THE ISTHMUS OF PANAMA DURING THE CONSTRUCTIVE PERIOD.

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H I S T O R I C A L

One of the chief difficulties that had to be overcome in the building of the canal across the Isthmus of Panama were the health conditions of the tropics. It became a recognized fact that the Canal project could not be carried on by Americans except the entire region be put on a secure health basis. Shortly before the American Government determined to build the Canal, it had been recently discovered and proved that certain mosquitoes were the carriers of the dreaded diseases of yellow and malaria fever so common in the tropics. The French forces prior to the American occupation had suffered immensely from the ravages of fever, but there was comparative freedom from yellow fever during the last seven years the French were on the Isthmus.

There were many theories as to how the fevers were contracted and carried from one person to another.

One prevalent idea that still holds in the minds of many people is that fever lurks in low, marshy and damp places and in some mysterious way gets into the human system. The damp and marshy places are still the principal factors in the propagation of the diseases and the connection between the two has now been proven to be the mosquito. It has been told for a positive fact that in the early days of the Panama Railroad when passenger trains crossed the "Mindi Swamp" between Colon and Gatun, the car windows and doors were closed to keep out the fever. Another idea that the medical authorities worked on in Havana, Cuba, was that yellow fever might be caused by filth, so they set about to clean the city. It did not reduce the number of cases of fever, but rather increased them.

The theory that malaria is carried by mosquitoes of the Anopheles species was demonstrated by Sir Ronald Ross of the British Medical Service of India, who came to that conclusion after a long series of experiments ending in 1898. A little later it was discovered that yellow fever is transmitted by the Stegomyia Calopus in the experiments carried out by Drs. Walter Reed, Jesse W. Lazear, James Carrol and A. Agramonte of the American Army in Havana in 1901.

In January of 1904, the quarantine of Colon and Panama was turned over to the Government of the United States and in June of the same year, the present permanent Sanitary Department was established with Col. W. C. Gorgas, who was previously Health Officer at Havana, as head of the Department, and Dr. H. R. Carter, fever expert, as director of Hospitals. The department immediately began its work of "cleaning the Isthmus" and the two first objective points were the cities of Colon and Panama. Malaria, typhoid and plague abounded in both of these places, the streets were unpaved and undrained and were commonly used as a dumping ground, making it practically impossible for vehicles to get from place to place. There was no system of water works in either of the places, so the people were dependent on cisterns for their water supply. The work of installing the water system was greatly hampered as there was only a small supply of iron pipe on the Isthmus, and it took a long time to get it from the States. There was a scarcity of other supplies, notably copper wire screening, which could not be purchased in the United States in large quantities. An epidemic of yellow fever broke out on the Isthmus in July 1904, about the time the first American employees were arriving, which lasted till

December 1905. This hastened the delivery of supplies and made it necessary for the Sanitary Department to work in great earnest. During this period there were 246 cases of yellow fever and 84 deaths of which 134 cases and 34 deaths were among Canal employees.

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VARIETIES & DESCRIPTIONS OF MOSQUITOES

The department in its anti-mosquito campaign endeavored to eliminate all breeding places and to maintain high standards of cleanliness in all of the settlements along the Isthmus. It was then of utmost importance to become familiar with the different varieties of mosquitoes so as to be able to identify them at a glance, to know whether they are carriers or not. The mosquito, like the fly, moth, and many other insects has four distinct periods of development in its life, namely the egg, larva, pupa and adult stages. The eggs of the adult mosquito are deposited on grasses or other objects near the surface of the water in such a manner that any disturbance of the surface will wash them in. Water is an absolute essential for the development of the mosquito and without it, it cannot propogate. The egg period

varies from 24 to 36 hours depending on the variety of the mosquito. It then passes to the larva stage in which form it is more commonly called a "wiggler" by the people of this country. This period lasts from 6 to 8 days, then comes the "pupa" stage of one day's duration. The adult mosquito emerges from the pupa shell full grown and lives from 6 to 10 or more weeks.

There are three distinct species that are common on the Isthmus, each one having their own peculiar habits and characteristics, making it very easy to distinguish them. It is absolutely essential to be able to identify the different varieties of the mosquito to determine whether they are carriers or not. Mosquitoes that are common on the Isthmus may be divided into three general classes as follows:-

1. Culex - common harmless variety
2. Anopheles - malaria fever carrier
3. Stegomyia - yellow fever carrier

There are ten varieties of anopheles and the following table gives their names and the percentage of them them that are infected. It should be stated that all anopheles do not carry malaria, only certain varieties.

1,	Albimanus - -	70.2%
2.	Tarsimaculata -	60.0%
3.	Pseudopunctipennis	12.9%
4.	Argyritarsis -	0.0%
5.	Gorgasi - -	0.0%
6.	Cruzii - -	0.0%
7.	Apicmacula - -	0.0%
8.	Malefactor - -	0.0%
9.	Eiseni - -	0.0%
10.	Franciscanus -	0.0%

There are four varieties of the anopheles that abound in any numbers, and they are the albimanus, tarsimaculata, pseudopunctipennis and the malefactor. It can be seen from the above table that the more common varieties are heavier carriers than the less common. The only frequent occuring anopheles that does not carry malaria is the malefactor. The anopheles may also be divided into groups according to their markings:

White Hind Foot Group:

Albimanus

Tarsimaculata

Argyritarsis

Leg Uniformly Colored Group

Pseudopunctipennis

Franciscanus

Spotted Leg Group:

Malefactor

Apicmacula

There are many ways of distinguishing the different varieties of mosquitoes in their various forms of life. Taking first the egg stage, it has been so far impossible to distinguish the eggs of the different varieties. It is very easy to identify the culex, anopheline and stegomyia larva without the aid of a microscope. The culex larva may be observed apparently hanging from the surface of the water with their bodies inclined at an angle of 45 degrees. They move in quick, short, jerky motions through the water from the surface to their feeding place. The anopheline larvae are extremely active and it is only by approaching the breeding place with caution that the observer may see them without disturbing them and cause them to seek places of safety. They dash through the water at great speed and hide in obscure places. The larva require air to breathe and have to come to the surface for it and may be observed at that time. The anopheline larva float on the surface of the water with their bodies parallel to it. They are darker colored than the culex, being very nearly black. An expert can distinguish some of the varieties in the

larva stage. The stegomyia larvae may be recognized by their "snake-like movements in the water and are longer than either the culex or the anopheles.

In the pupa stage, they are all more or less similiar, however the anopheline pupae may be distinguished from the pupae of the culex and stegomyia as being smaller and darker colored.

With a little experience in observance, the different classes of adults may be readily identified. First, the culex which is the most common and harmless can always be recognized in a resting position, as the body of the mosquito is parallel to the object it is restin on. The anopheles holds its body when resting at an angle of about 45 degrees. They usually rest on vertical walls and surfaces and dark hanging objects, seldom on ceilings, and in one instance, one was seen resting on a horizontal surface but this is exceedinly rare. The albimanus and tarsimaculata are practically alike, differing only in the number of rings of white and black on the end of the proboscis. The last segment of the hind legs of the two varieties is white, the legs are held up in a curved position at the back of the body, and are not used in supporting the weight of of the mosquito when at rest. The pseudopunctipennis

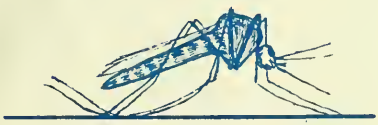
is rather of infrequent occurrence, but may be distinguished by the curved and uniformly colored legs. All anopheles have mottled or spotted wings, culex have plain wings, and the stegomyia have plain wings with heart-shaped markings on the back only visible through the microscope. The malefactor, which is harmless so far as being a carrier of malaria is concerned has a slightly wider wing than the other anopheles and whereas other anopheles have three distinct spots on each wing, only two are pronounced in the malefactor. The legs of the malefactor extend straight out from the back, which is another distinguishable feature. These descriptions should enable the average observer to distinguish the different varieties of mosquitoes occuring on the Isthmus.

CULEX – (Culicine)

Mosquitoes that do NOT transmit Malaria

ANOPHELES – (Anopheline

Mosquitoes that DO Transmit Malaria



Culex – Adult

Body Parallel to Surface

Anopheles – Adult

Body at an Angle to Surface

Head of Culex Female

Head of Culex Male

Head of Anopheles Male

Head of Anopheles Female

Culex Larva & Pupa

Body at angle to Water Surface

Anopheles Larva

Body Parallel to Surface of water.

5715. Sketches from Reduction of Placard of Pasteur Institute, Paris.

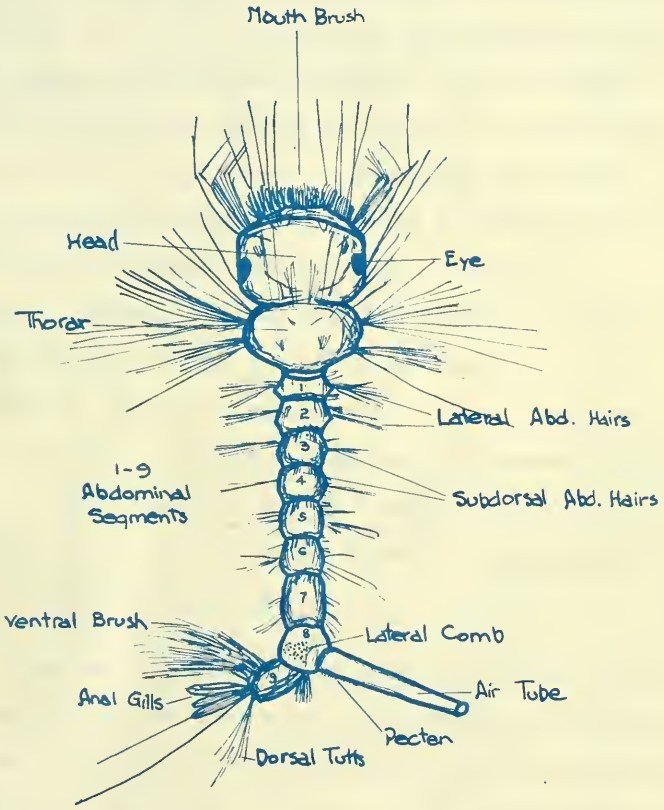


DIAGRAM OF A CULEX LARVA

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HABITS OF THE DIFFERENT VARIETIES.

No hard and fast rules may be laid down in regard to the places where the different mosquitoes propogate, but some general characteristics of the varieties may be formulated. The culex prefer to lay their eggs in still water and the larvae can live in stagnant and polluted water. This makes it essential that any container that will hold water should be destroyed or placed in such a manner that it will not remain a container. Broken bottles, old tin cans, and watering places for fowls are the most frequent among the list of containers, and great care should be exercised so as to remove all possiblity of having containers about a house. The culex are not so liable to be found in running water, but where the current is sluggish they are occassionally found.

The anopheles are much more particular about there breeding places for they require and prefer running water. They sometimes occur in the hoof-prints of cattle when the water is fresh. The algae growth in the bottoms of shallow slow flowing streams makes ideal breeding places for the anopheles, the algae being a plant growth which is their food supply and also makes a harboring place for them. Anopheles are commonly found in drainage ditches that are filled with

a rank growth of weeds and grass and the current of the water having been nearly stopped. The method of determining the presence of anopheles in such a case is quite easy. The inspector who carries a small dipper or saucer in his pocket, dips up some of the water, being careful to do it before the larvae have a chance to hide in inaccessible places. When it is desired to know the particular variety captured, some of the larvae may be taken to the office of the Inspector and there permitted to develope to the adult stage in a screened enclosure.

The breeding places of the larvae of stegomyia is always in containers with culex larvae in the immediate vicinity of the dwellings of human beings, and are often known as the "domestic" mosquito. The stegomyia prefer fresh water and the more putrid the water, the more culex there will be present. Stegomyia and anopheles are not common in the same water, but they may occur in large containers where vegetable matter is abundant. The most common place of finding the stegomyia is in the rain barrels that are used in collecting the runoff water. Should people living in isolated districts move away and leave containers with stegomyia larvae present, they will soon disappear. This fact has been clearly demonstrated in a number of cases on

the Isthmus. They do not occur north of the frost line, but when they do, it is probably because they were carried either in the larva stage or the adults were carried by people. Water casks often contained stegomyia larva and this can account for yellow fever on shipboard in the old sailing days. It is said that when the Americans took charge of the hospitals at Colon and Ancon, that to prevent ants and other crawling insects from getting into the beds, each bedpost had been set in a small dish of water, which was an ideal breeding place for stegomyia. So that it is possible that many cases of yellow fever were developed after the patients arrived at the hospital for ather treatment. The question has often been asked "How many times does a mosquito have to bite a person in order to transmit fever?" In the case of stegomyia, one bite is sufficient to give yellow fever, but with the anopheles it is not so easily determined for much depends on the physical condition of the victim and the degree of infection of the mosquito. An ordinary person can withstand a dozen or more bites from infected anopheles while some can withstand a hundred bites and not have it immediately. Persons living in communities where there are infected anopheles and are bitten frequently or infrequently will sooner or later have malaria.

The anopheles are as a rule not active during the day, but at certain seasons of the year, they have been known to bite a person in the sunlight. The stegomyia bite more often in the afternoon, and usually around the legs and that may be the reason why putees are worn both by men working in the office and in the field.

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METHOD OF CONTAGION

The theory of the method of contagion is that an adult stegomyia must first bite a person infected with yellow fever, and then after a period of 12 days it is capable of transferring the disease to a person not infected. The mosquito in itself gives fever and it has been further demonstrated that the stegomyia is the only carrier of yellow fever, and the anopheles, the malaria.

THE DEPARTMENT OF SANITATION.

After becoming familiar with the traits and characteristics and modes of habitation of the different kinds of mosquitoes, the work of the Sanitary Department was very much simplified. The department had the fundamental principals to work on following the experiments in Havana and it was still to be demonstrated that the theories would work out on a large scale. This work was carried on by a corps of Sanitary Inspectors under the immediate jurisdiction of the Chief Sanitary Inspector. The total area over which the sanitary work extended was more than 100 square miles, subdivided into districts with the number of Inspectors assigned to each district as follows:

1. Balboa - - 1.
2. Ancon - - - 1.
3. Corozal - - 1.
4. Miraflores - - 2.
5. Pedro Miguel - 2.
6. Paraiso - - 1.
7. Culebra - - 2.
8. Empire - - 2.
9. Las Cascadas - 1.

10. Bas Obispo - - 1.
11. Matachin - - 1.
12. Gorgona - - 1.
13. San Pablo
14. Tabernilla - - 1.
15. Frijoles - - 1.
16. Gatun - - 4.
17. Porto Bello - 1.

The personnel of the Division of Zone Sanitation is as follows:

1 Chief Sanitary Inspector
1 Assistant Chief Sanitary Inspector
2 Division Inspectors
26 District Inspectors
1 Entomologist
18 Foremen and 226 Laborers

A book of instructions has been compiled for the guidance of Sanitary Inspectors in the performance of their duties which sets forth the making out of routine and special reports, building and screening regulations, fumigation, disinfection, etc. The Inspectors are required to be familiar with the appearance, life history and habits of the anophelines, stegomyia and culicenes. They are expected to be able to distin-

guish these species in their larval and adult forms, and to be familiar with the different methods of mosquito eradication. In addition they are expected to be familiar with the breeding habits of the house fly and the usual methods of their extermination.

Work of the Canal Zone Sanitation.

The work done by the Division of Canal Zone Sanitation (not including the cities of Colon and Panama) may be classified in the order of its relative importance and magnitude into

(1) Anti-malaria work
(2) Anti-yellow fever work
(3) Anti-plague work
(4) Anti-typhoid and dysentery work
(5) General Sanitary Work

The anti-malarial work is most important from the standpoint of the Sanitary Inspector for it claims by far the largest portion of his time and efforts and the efficiency of the station is gauged by the number of cases of malaria sent to the hospitals during the current month. Each month a report is received from the Chief Sanitary Officer giving the "standing" of each station and the rate of malaria.

The anti-malarial work carried on by the Division of Canal Zone Sanitation may be subdivided into the following heads:

A. Elimination of breeding places of Anophelines

(1) By filling.

(2) By drainage-- sub-soil and surface.

(3) By admitting sea water into fresh water areas

(4) By cleaning and training the banks of streams and stagnant bodies of water.

(5) By brush-clearing and grass-cutting.

(6) By concreting ditches in permanent districts.

(7) By the introduction of fish into reservoirs and other bodies of water where oiling and treating with "larvacide" would be impracticable.

(8) By oiling, either by hand or automatic drip devices.

(9) By periodical application of larvacide.

(The last three methods also serve to destroy whatever larvae happen to be in the areas treated.)

B. Destruction of larvae.

(1) Oiling with crude oil.

(2) Application of larvacide.

(3) Introduction of fish.

C. Destruction of Adult Anopheles.

(1, Catching and killing with the aid of a tube containing a cotton wad saturated with chloroform.

(2, Catching in traps.

(3) Fumigation.

Elimination of Breeding Places.

The elimination of breeding places by means of drainage is perhaps the most common method that has been adopted, but this is always subject to the topography of the surrounding country. However, it may be said that in the seven years of experience of the Department, it has been proven that the open earth ditch under tropical conditions is wasteful in cost and effort. The unlined ditches are expensive and unsatisfactory makeshifts, only to be adopted when the work is of a very temporary nature or as a preliminary to the installation of subsoil drainage.

Sub-drainage is far superior to open ditches in every way and should be used where ever conditions are favorable. Ditches for sub-soil drainage must be cut to a true grade and should be made as narrow as possible so as to reduce the amount of cover stone

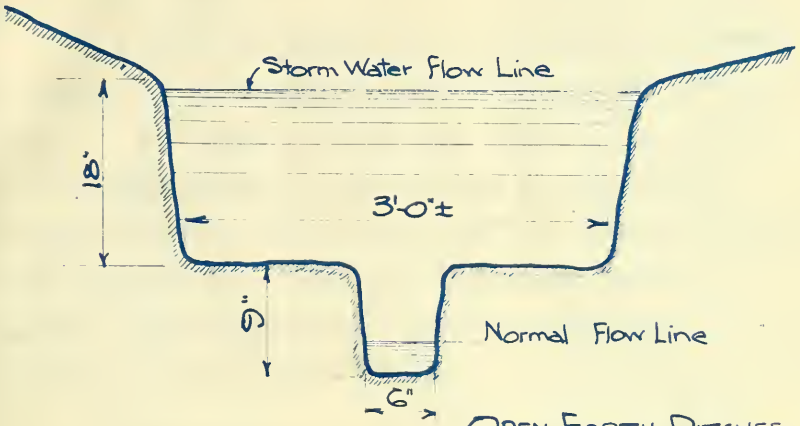
necessary. In narrow ravines is more suitable, a trench is dug, a tile laid in the bottom and covered with stones and cinders. The tile should be laid to true grade with open joints of about 1/8 inch, and then be covered over with field stone of about 4 to 6 inches in diameter. When the soil over the stones is covered with vegetation, the spaces between the cover stones does not fill up. Water will find its way through the joints into the tile line. The grade should not be less the 1% , and special care should be taken to have the outlet of the tile kept clear at all times. Some drains that have been in use over three years have not had one cent expended on them for maintenance since they were installed.

Where surface ditches are the only alternative, there are some principles to be borne in mind in laying them out so they will be most effective. When a side hill drains into a level area, the ditches are to be located at the toe of the slope around the edge of the hill, so as to catch the water before it spreads out over the level area. Some difficulty had been experienced in a particular area of the Gatun District where the above conditions prevailed. Many ditches had been cut across the level area in an effort to drain it, and finally the scheme outlined above with the ditches at the toe of the slope was adopted, which proved very satisfactory.

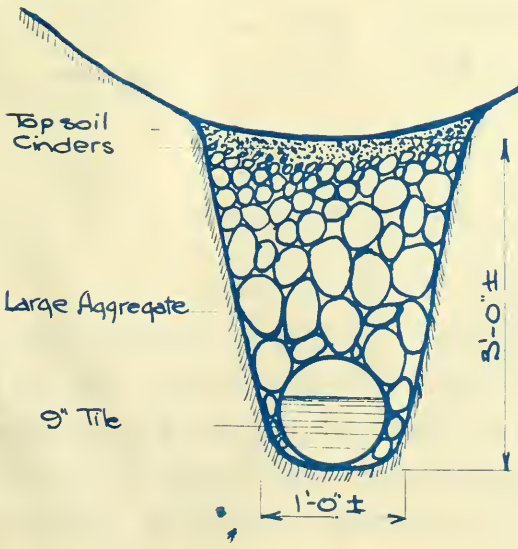
In Gatun, a novel section has been adopted to meet certain conditions of drainage and has proven very successful in the case mentioned in the preceding paragraph. It was required to provide for a steady flow of small cross-section and at the same time be able to take care of storm water without over flowing the banks. A wide ditch was cut (see sketch on following page) about three feet wide and one and one-half feet deep, and in the center of the bottom was cut another ditch of smaller cross-section. The large section was designed to take care of the storm water while the narrow section in the bottom was for the natural drainage. The object of the deep narrow section was to reduce the surface exposed, increase the depth and velocity as much as possible. Had this same amount of water been permitted to spread out over the bottom of the wide section, it would have been very shallow, and the flow would have been very sluggish, which would bevery favorable for the breeding of anopheles.

Another ingenious scheme to prevent the streams from being choked with weeds and grass where the open ditches were to be permanent was to concrete the bottoms. Ashell of concrete, varying in thickness from four to six inches, was laid to grade, and in this way, a permanent ditch with a uniform velocity was obtained. Seven miles of these ditches were laid in Gatun District up till July, 1913.

Special Forms of Drainage Ditches
in the Canal Zone



Open Earth Ditches
Special Cross-Section Adopted in the Gatun District to Accommodate Normal & Storm Flows



Subsoil Drainage Ditch
Section Adopted in Steep Vegetated Ravines

S.M.S.

Clearing and Training of Banks.

Pockets and irregularities in banks of streams and vegetation in the water are most favorable breeding places. The banks are kept free from pockets and well above the high water so as to be free from vegetation. One method adopted to some extent was the burning of grass on the edges of the stream, but as this was neither premanent nor satisfactory, it was only used where there was no other alternative.

The banks are trimmed and lined with stone where ever necessary; the pockets filled or cut away, and the courses of the streams straightened. Algae growth can be destroyed with a solution of copper sulphate or larvacide which will be described later) or be raked out onto the high ground and burned.

Introduction of Fish.

The introduction of fish into the streams and reservoirs from which water supplies are derived has met with much success on the Canal Zone. A variety of fish known as "Millions", a very small top minnow of the species Gerardinus occuring only in waters surrounding the Island of Barbadoes off the north coast

of South America has been used for the purpose of destroying the larvae. Under the climatic conditions of the Zone, these fish multiply very rapidly, and this has proved a successful method in the destruction of larvae where larvacide and copper sulphate cannot be used. The introduction of fish is however not nearly as efficient as the use of larvacide and is only to be recommended for large bodies of water. In order that the fish may have ready access to the mosquito larvae, it is necessary to keep the banks as free of vegetation as possible and to train them so as to prevent small collections of water being separated from the main body. The Rio Grande reservoir was one of the sources of water supply for Culebra and the towns west, and a gang of six to eight men were kept constantly busy cutting the grass and training the banks. It took about three months to make the entire circle of the reservoir and in that time, the grass had grown to a height of three and four feet. Anumber of tests were made of the water on the edges and they failed to reveal any larvae. Although no copper sulphate had been used, the absence of larvae may be explained by the surface movements of the water which prevented the larvae from breathing on the surface. One of the Sanitary Inspectors had been working along this line and was devising some mechanical means of producing a surface movement.

Views of Frijoles from the Sanitary Office.

A small concrete "test pond" was built near the office of the Sanitary Ispector at Frijoles, and "millions" were introduced into it. Although the entire surface was exposed, no larvae were ever found.

Oiling.

The surface of stagnant bodies of water that are not drainable, and sluggish flowing streams were given an application of crude oil. The object of the oil is to produce a thin film on the surface which will prevent the larvae from breathing. The larvae are not able to puncture the oil film with their breathing tube and will drown if they cannot get air.

The crude oil used in this connection comes from Southern California in great tank boats and is stored in steel cylinders of about 20 feet in diameter. It is a heavy asphaltum base oil and is used just as received without altering the constituents. The method of application varies with the area to be treated. An automatic drip device has been used in streams of moderate flow and has proven very satisfactory. An ordinary galvanized iron ash can of about 30 gallons capacity serves the purpose very well. A hole 2"x3/8"

is made in the sides about three inches from the bottom. Into this opening is soldered a flat spout 1 3/4" wide, 1, 4" high and 2 1, 2" long into which is inserted an ordinary lamp wick. The rate of flow can be regulated by compressing the spout until the oil drips with sufficient rapidity to give a good oil film. TO prevent a clogging of the wick, a sufficient amount of water was placed in the bottom of the can extending within an inch or so of the wick.

In order to be efficient, these cans are mounted two or three feet above the surface of the water to which the drip is to be applied, so the drops may strike the surface with sufficient force to be broken up.

Large bodies of stagnant water are oiled by the periodical application of a thick layer of oil, and is repeated whenever the layer is broken up by rains, floods, winds, etc., When the prevailing winds blow steadily from the same point of the compass, the oil layers on pools shift to the leeward exposing a more or less extensive surface. To prevent this shifting, planks and timbers have been anchored at intervals along the windward portion of the pools.

The secret of successful oiling is a continuous oil film. Vegetation protruding through the oil layer destroys the continuity unlessthe oil layer is very thick, and it is surprising how quickly a mosquito larva will find a small fault in a large oil surface.

A simple method of obtaining automatically a thin layer of oil has been adopted on streams of low velocity. A bundle of common cotton waste is soaked in crude oil and dropped into a stream with a stone attached to it to keep it from floating down. This bundle of waste slowly casts off the oil and a very satisfactory oil layer results. A similar scheme was arranged in the Miraflores District where ditching would not drain a certain area. The ground at this place was spongy and held a great deal of water for a long time after it had rained and it took several weeks for it to dry out. A barrel with holes in the bottom was sunk in the ground even with the surface., and was filled with oil soaked waste. When ever the area became saturated with water, the water would enter through the holes in the bottom forcing a portion of the oil into the surface which escaped making a thin oil film, which covered the surrounding area. Three such barrels were placed on the up-hill side and were suffi-

cient to take care of the area.

In some places the grass on the edges of the streams is burned by a special grass-burner which may be described as follows: A small barrel fitted with a Myer's Barrel Pump is filled with a mixture of 90 parts of crude oil and ten parts of larvacide. To the pump is attached a 50-foot length of 1/2" hose, terminating in a 6-foot 1/2 inch pipe with a spray nozzle at the end. The fire is started at the windward end of the ditch and the spray of oil mixture is directed into it. As the fire spreads, the spray is advanced to the leeward. Three men with this apparatus will burn about 600 feet of ordinary ditch in eight hours at a cost of about 2¢ per running foot.

Larvacide

The larvacide as manufactured on the Isthmus is prepared from crude carbolic acid, a substance containing 5% to 30% of tar acids with a large amount of inert oils. The crude acid is immiscable with water and is therefore a very inefficient disinfectant on account of its inability to come in contact with the micro-organisms. However, when the crude acid is made into a liquid soap by heating with resin and alkali, a product results which emulsifies on the addition of a

large amount of water. The product is not only most effective in the destruction of larvae but is also valuable and cheap disinfectant.

Method of Manufacture:- The chemical requirements of the crude carbolic acid call for a specific gravity of not greater than 0.97 and to contain not less than 15% of tar acids. Each shipment is assayed at the laboratory for it is necessary to keep the product of a specific gravity approximately that of water so that it will diffuse rapidly and neither sink to the bottom nor remain on the surface. One hundred and fifty gallons of crude carbolic acid are heated in an iron tank having a steam coil with steam at a pressure of fifty pounds to a temperature of 212 degrees F. Two hundred pounds of finely sifted common resin are dissolved in the heated acid and thirty pounds of sodium hydroxide dissolved in six gallons of water are added. It is stirred by means of a mechanical stirring rod attached to the edge of the tank. The product will yeild about three and one half barrels at a cost of 15¢ per gallon.

As a mosquito larvacide it is mixed one part of larvacide to five of water, and is used by spraying the margin of pools and ponds or other mosquito breeding places, so that the resulting dilution of the larvacide has a thin milky opalescense representing approximately a dilution of 1 to 5000. Tests are made of the larva-

Cide noting the time it will require a dilution of 1 to 5000 to kill the larvae or the time they leave the surface and are unable to return. This larvacide will kill mosquito larvae in a 1 to 1000 emulsion in water in 1 to 5 minutes and a 1 to 5000 in one-half hour. Anopheline larvae are slightly more resistant than culex larvae, and all pupae are more resistant than larvae to the effects of the larvacide.

With a larvacidal agent so destructive to mosquito larvae, it is natural to inquire how often will it be necessary to reapply the larvacide for the purpose of destroying the mosquito larvae. Assuming that mosquito eggs have just been laid on a pool, it will be necessary to reapply before the brood pupates, for pupae are more resistant to the powers of the larvacide and the latter cannot be depended on to destroy them. It has been found by Dr. Darling that by breeding anophelines in the laboratory that an anopheles albimanus egg period is about 36 hours, the larva period 9 days and the pupae about two days. As these periods are likely to be a little shorter out of doors where there is abundant food and sunshine, the larvacide is applied every seven days. In this way all broods are destroyed in the larval stage and thus prevent breeding.

Destruction of the Adult Mosquitoes.

The success of destroying the adult mosquito far exceeded the most optimistic expectations of the members of the Department. The two methods that have given the best results are the catching by hand and the catching in traps.

In the hand catching, use is made of a glass tube about five inches long and one inch in diameter. In the bottom of this tube is placed a layer of cut rubber bands, then a layer of cotton which is covered with a couple of circular pieces of blotting paper, exactly fitting the tube. The "wad" is then saturated with chloroform and the tube is kept corked except when in use. In the capturing and killing of a mosquito that may be at rest on an object or wall, the tube is cautiously placed over it, being careful not to disturb it; the mosquito perishes in the fumes of the chloroform, and drops into the tube. By this method it is possible to catch every mosquito in a room, as they are caught one at a time and one may be killed without disturbing others resting on the same object. A mosquito having had a blood meal during the hours of darkness becomessluggish and will come to rest on the nearest object, usually choosing a dark-

colored surface so as to be less noticable, or light on the screening of the doors and windows where they may hope to escape and are easy victims for the mosquito catchers. A mosquito seems to have the "ability" of finding even of the smallest openings that give entrance into a house, but are not able to find their way out again. As many as 300 anopheles have been caught in a single box car that was being used as sleeping quarters.

When hand catching was first begun on the Isthmus, it was thought that only experienced and educated white men would be able to carry out the work, but much to the surprise of the Department, the Jamaican negro has been trained to do this work most efficiently. The work is monotonously routine, and this feature seems to fit the exact nature of the negro, to do the same thing over and over again. Two rounds of all the quarters are made daily and at the end of the day's work, a record is made of the number of the different varieties caught. The negro becomes very efficient in distinguishing the various adults, and can tell the name of the specie as soon as he sees it.

This method of hand catching was the only means of malarial control adopted in the District of Frijoles, embracing the native settlements of Frijoles, Monte Lirio and Camp Purdum and has given success at a

Office of the District Sanitary Inspector at Frijoles.

The Sanitary Gang -- Natives of Jamaica.

low cost. The malarial rate has been practically as low as the average rate in the settlements where extensive sanitary work is being done, despite the fact that no larve destruction or breeding place eradication has been carried on in the district. It has been an experimental station to determine the efficiency of hand-catching only as a means of malarial control, with the idea in view that this method might be adopted in the other permanent where expensive work is now being carried on.

Catching by means of traps has been successfully tried out in some of the districts. In localities where there is a considerable flight of mosquitoes such as in Corozal and Miraflores, three times the number of mosquitoes have been caught in the traps than were caught by hand with the most careful daily work. They have not been quite as sucessful in the Gatun District. The trap has also been successfully used for fly catching,

The traps are installed in two ways, either to catch the mosquitoes when they endeavor to enter the building or when they attempt to leave it. Both methods are usually combined by installing several traps in each building. The traps intended to catch mosquitoes attempting to enter the building are always installed on the leeward side for experience has demonstrated that

trap catching is mich less successful on the windward side. Each day the traps are removed and fumigated, thus killing the mosquitoes.

Flight Habits of Adults.

The adult mosquitoes of all varieties are more active in flying at sunrise and sunset than at other times of the days. At sunset, they may be seen hovering near the doors and windows of all quarters awaiting an opportunity to get inside.. In the morning, the majority of those that did get in may be seen on the window screens attempting to find a way out. Those that have had a blood meal alight on dark objects where they are not liable to be disturbed.

A number of "flight" experiments were conducted in the Gatun District during March 1913, and some of the old rules relative to the distances mosquitoes would fly were broken down, and many new discoveries were made. The experiments were the immediate result of an unaccountable influx of mosquitoes in the Gatun District during the month of January, which puzzled the entire department for several weeks. Large numbers of adults were being caught in the traps and by hand, and additional laborers were put to work to help catch as

many of the adults as possible. In the meantime, the District Sanitary Inspector with his assistants were searching every possible place where larvae might be breeding, but failed to find any breeding places in proportion to the number of adults that were being caught. The general accepted rule up to this time had been that mosquitoes did not fly more than 300 or 400 yards from their breeding places, but every place within a mile of Gatun had been thoroughly gone over without locating the source of the mosquitoes.

It happened one day that the Inspector visited a section of the district where a hydraulic fill was being made some mile and one-half from Gatun. A dredge working in the canal was pumping the excavation and the seawater to this section, and here it was found that the anopheles were breeding by the millions. It was sufficiently evident that this was the source of the mosquitoes but the department had to prove that the influx of mosquitoes were coming from this breeding place. A cage or trap was located under one of the buildings in Gatun, a lantern hung under it so as to attract the mosquitoes and in this way, several thousand would be caught. They would be carefully sprayed with a special dye with the aid of a common atomizer. Theye were then taken to the breeding place and liberated. In a few

days, colored mosquitoes showed up in the traps and hand catches which proved without a doubt where the mosquitoes were coming from.

Another interesting discovery was made in reference to the time of the flights. It was discovered that the flights began about 5:30 a.m. lasting until 6:30 or 7:00 a.m. and begin again in the evening between the hours of 6and 7. The variety that was coming from the seawater area was the anopheles tarsimaculata, while the albimanus that were being caught were coming from other breeding places.

Anti-Yellow Fever Work.

No case of yellow fever has originated on the Isthmus since May 1906, but never-the-less the efforts toward stegomyia eradication have not been lessened. In vilages it is of first importance to prevent the accumulation of water in containers where stegomyia might breed.

Some of the methods of prevention that have been adopted is the elimination of roof gutters, except self draining short gutters over entrances, and no water containers are permitted at any house within a

300 foot radius of a water supply. In localities of more than 300 feet, only screened containers are allowed providing certain requirements are fulfilled. The containers are required to be screened according to directions issued by the Sanitary Department and as water barrels are most generally used, each is required to be fitted with a spigot. With all of the care, culex larvae were found in the water barrels. The only explanation that could be given was that the barrel had been brim full and that the water had extended above the wire meshing at which time eggs were deposited on the water. As the water was withdrawn, the surface was lowered and became inaccessible to the adult. To prevent this from occurring, the barrels were required to have a hole bored about three inches from the top of the barrel and be covered with screening.

The stegomyia eradication measures on the Canal Zone have been so successfully carried out that an adult stegomyia is a great curiosity and it is becoming difficult to obtain stegomyia larvae in the sanitated area. Only on one occassion did the writer find stegomyia larvae, and they were in an unscreened water barrel at a camp of some Hindu laborers.

Anti-Plague Work.

A campaign of rat destruction is being carried on in all the districts of the Zone, especially in the settlement of Balboa, where the docks are located for all the Pacific Liners. Within four day's travel is located the city of Guayaquil where plague is common, and the quarantine laws are rigorously enforced on vessels plying between these ports.

In the course of rat destruction it has been found that rats soon learn to avoid the traps if the same type is continually used. The same may be said of poisoned bait so that it is necessary to change frequently both the poisons and bait. All traps are carefully scrubbed and sterilized in a solution of larvacide after each catch. When the rats are caught alive, they are placed in zinc-lined boxes and sent to the laboratory at Ancon where they are combed to discover whether they are infected with fleas. It is a well known fact that the rat flea is the carrier of the plague.

One of the earliest measures adopted by the Sanitary Department was to require that all dwellings be either elevated not less than three feet above the ground or have the concrete floors laid directly on

the ground. The object of the measure was to prevent a collection of rubbish under the houses where rats might propagate.

General Sanitation.

The work of general sanitation includes grass-cutting, screening, fumigation, building inspection and many other things. In the tropics in the rainy season, a common specie of grass has shown an actual growth of 32 inches in 28 days. The tall grass furnishes shelter to the adults and tends to hide breeding places, and it also prevents the evaporation of small puddles formed by rains, and also hides from view containers that may have been thrown in the grass.

All grass is kept trimmed low within the settlements and is cut low along the banks of streams and swampy areas and places in which water might collect through seepage or rain anywhere within a possible mosquito flight distance of a settlement. The total amount of grass cut per year is about 4000 acres.

All Commission Buildings are thoroughly screened and it is the duty of the Sanitary Inspector to see that the screening is mosquito-proof and in good repair.

Results.

It would be perfectly pertinent to ask the question, "What results have been obtained by the expenditure of all this work and money.?"

The Sanitary work in the Canal Zone has been of a three-fold value:

(1) The efficient organization has been maintained in the service of the Isthmian Canal Commission because of the high sanitary measures set forth, thereby eliminating yellow fever entirely, controlling malaria, and making the Isthmus one of the most healthful places in the world.

(2) Sanitation has been a success from an economical standpoint, both in preventing loss through absence from work because of illness, and increasing the efficiency of the men at work. In 1906, there were 233 deaths among employees from malaria, while there were only 50 in 1910.

(3) Sanitary work on the Canal Zone has served to bring the attention of the world to the possibility of making the tropics habitable for the white people, and that the cost of bringing this about need not be prohibitive. The medical and hospital care of the employees and their families has cost the government

two and one half cents per day per capita, and the Sanitation 9 mills per day. These figures are well within the financial ability of any tropical country.

For some of the information embodied in this paper, I am indebted to the following writers and their works:

Sir Ronald Ross -- "The Prevention of Malaria."

A. J. Orenstein, M.D. -- "Sanitary Inspection Inspection of the Canal Zone."

S. T. Darling, M.D. -- "A Mosquito Larvacide Disinfectant and Methods of its Standardization."

Department of Sanitation, W. C. Gorgas, Chief Sanitary Officer, -- "Manual of Instruction for Sanitary Inspectors.

John O. Collins, --"The Panama Guide."